International Journal of Dairy Science and Technology Vol. 1 (3), pp. 056-060, November, 2014. Available online at www.advancedscholarsjournals.org © Advanced Scholars Journals

Review

The Impacts of vitamins and trace-elements supplementation on milk production in dairy Cows: A review

Wang Cao

Department of Animal Science, Faculty of Agricultural Science, Hong kong Baptist University, Kowloon tong, China.
E-mail: caowang@yahoo com.ir

Accepted 30 October, 2014

During the past decade, significant advances were made in understanding the effects of vitamins and trace-elements supplement on milk production of dairy cows. This work discussed the effects of vitamins and trace-elements supplementation on milk production of dairy cows. Studies have indicated that vitamin A (VA) and β-carotene (BC) supplementation have some effects on udder health and milk yield in dairy cows whose intake is below 110 IU/kg BW/day. If low quality forage is fed, supplementation of VA should be considered. Supplementation of B-vitamin has important effects on milk production and could increase milk yield and milk component production. The effect of vitamin E (VE) and selenium (Se) supplementation on the milk yield and milk components are not unified due to the optimum dose, route and timing of VE administration in lactational dairy cows. Zinc (Zn) supplementation increases lactation performance and reduces milk somatic cell count (SCC) in most studies. Limited research has indicated that copper (Cu) supplementation could reduce milk SCC. Before deciding to supplement vitamins and trace-minerals indicated earlier for the improvement of milk production of lactational cows, farmers should have their animals fed with tested and evaluated rations to be sure of the levels of supplementation which may be warranted.

Key words: Vitamin, trace-element, dairy cow, milk production.

INTRODUCTION

Vitamins and trace-elements have long been recognized as a requirement for reproduction due to their cellular roles in metabolism and growth. However, they also have specific roles and requirements in lactational cows, they are: vitamin A (VA), β-carotene (BC), B-vitamin, vitamin E (VE), selenium (Se), zinc (Zn) and copper (Cu). Many of these micronutrients have antioxidant activities that are beneficial to animal health and milk yield.

Their concentrations often decrease around calving and extra supplementation is recommended in some dairy herds. However, their requirement varies, for example, depending on the quantity and quality of feedstuffs in the diet. During the past decade, significant advances have been made in understanding the effects of vitamins and trace-element supplements on the milk production of dairy cows (Girard and Matte, 2005; Griffiths et al., 2007; Bourne et al., 2008). Recent reviews have focused on the roles of vitamins and trace-minerals in immune function and disease resistance in cattle (Spears, 2000; Weiss and Spears, 2006), and the roles of antioxidants and trace minerals on immunity and health in transition cows (Spears and Weiss, 2008). However, there is very limited literature on the roles of micronutrients on the milk production of dairy cattle. This paper reviews the current knowledge of the effects of vitamins and trace-element supplements on the milk production of dairy cows.

Abbreviations: VA, Vitamin A; **BC,** β-carotene; **VE,** vitamin E; **Se,** selenium; **Zn,** zinc; **Cu,** copper; **Mn,** manganese; **Co,** cobalt; **SCC,** somatic cell count; **CMT,** California mastitis test; **DM,** dry matter.

VITAMIN A AND β-CAROTENE

VA and its precursor-BC are important in maintaining epithelial tissue health and play a vital role in mucosal surface integrity and stability (Sordillo et al., 1997). These functions may affect cow resistance to pathogen entry into the mammary gland as well as resistance to post-entry. In addition, BC appears to function as an anti-oxidant, reducing superoxide formation within the phagocyte, and it is an important free radical scavenger. Cows with higher California mastitis test (CMT) scores had significantly lower plasma VA and BC concentrations than cows with CMT scores, indicating no mastitis. Jukola et al. (1996) reported that VA and BC supplementation have an effect on udder health only when the plasma level of VA is lower than 0.4 mg/L and BC is lower than 3.0 mg/L. However, several studies have shown no im-pact of supplementing BC on intramammary infection level (Heinrichs et al., 2009).

An increase in milk yield to the extent of 6 to 11% on BC supplementation at 400 mg/day per cow has been reported (Aréchiga et al., 1998). However, supplementation with VA (550,000 IU/day) exceeded daily requirements about 8-fold for up to 2 months to dairy cows during the dry period, which have slightly decreesed energy-corrected 100-d milk yield and milk fat yield (Puvogel et al., 2005), possibly because of enhanced apoptic rates of mammary cells.

Diets based on good quality silage or fresh forage probably provide adequate BC, and supplementation would not be economical. If low quality forage is fed, supplementation should be considered. Supplementation of VA is likely not needed in excess of normal recommendations. The level currently recommended (NRC, 2001) is 110 IU/kg BW/day for milking cows.

B-VITAMIN

In the past several centuries, dairy cows have greatly increased their average milk and milk component yields. It is likely that their B-vitamin requirements increased accordingly and that ruminal synthesis alone may not be sufficient to meet the new needs, even though mature ruminant animal's rumen microflora could synthesize a certain amount of B-vitamins. In recent years, several studies have well documented that B-vitamin supplementation has important effects on the milk production of dairy cows.

Majee et al. (2003) used supplemental biotin (20 mg/day) and a B-vitamin blend [thiamin (150 mg/day), riboflavin (150 mg/day), pyridoxine (120 mg/day), B12 (0.5 mg/day), niacin (3000 mg/day), pantothenic acid (475 mg/day) and folic acid (100 mg/day)] in early lactation multiparous cows with a 28 day period and the results showed that milk yield was increased (1.7 kg/day) for supplemental biotin at 20 mg/day alone, while yields of milk protein and lactose but not fat were higher for supplemental biotin and the B-vitamin blend. In a study by Sacadura et al. (2008), supplying early lactation cows with a ruminally protected B-vitamin blend (3 g/cow/day), which contained biotin (3.2 mg/g), folic acid (4 mg/g), pantothenic acid (40 mg/g) and pyridoxine (25 mg/g) for a 35 day period, resulted in milk and milk component yields increasing with B-vitamin feeding, especially milk protein yield. It can be suggested that the mechanism leading to the positive overall production response with B-vitamin supplementation was due to improvements in metabolic efficiency of intermediary metabolism, rather than increased metabolic activity. However, in a study by Rosendo et al. (2004), multiparous Holstein cows received 0 or 20 mg of biotin/day starting at an average of 16 days prepartum and then switched to 0 or 30 mg of biotin/day from calving through 70 days postpartum. The results showed that milk production (35.8 vs. 34.8 kg/day) and milk fat concentrations (3.59 vs. 3.69%) were similar, and indicated that lactation performance was not improved by supplemental biotin.

Shaver and Bal (2000) evaluated the effects of dietary thiamin supplementation on milk production of dairy cows. 88 Holstein cows were blocked by parity and assigned randomly to either placebo or thiamin top-dress for the 8-week experiment to provide a supplemental thiamin intake of 0 or 150 mg/day per cow. Within each of these groups, cows were further assigned randomly to two total mixed rations (TMR) for 4 weeks, with the TMR treatments which then reversed a second 4-week experimental period. Milk yield was 2.7 kg/day higher for thiamin-supplemented cows. Yields of milk fat and protein were increased (0.13 and 0.10 kg/day, respectively) by dietary thiamin supplementation.

Graulet et al. (2007) demonstrated that supplementary folic acid (2.6 g/day) from 3 weeks before to 8 weeks after calving increased milk production by 3.4 kg/day (P = 0.01) and milk crude protein yield by 0.08 kg/day, and between 45 days of gestation and drying off, supplementary folic acid tended to increase milk production by 1.5 kg/day (P = 0.09). Girard and Matte (2005) found that milk production was increased linearly with the quantity of folic acid ingested (0, 2 or 4 mg/kg BW/day) in multiparous cows from 4 weeks before the expected time of calving until 305 days of lactation.

VITAMIN E

VE is an important lipid soluble membrane antioxidant that enhances the functional efficiency of neutrophils by protecting them from oxidative damage following intracellular killing of ingested bacteria (Herdt and Stowe, 1991). Fresh green forage is an excellent source of VE; however, concentrates and stored forages (hays, haylages, and silages) are generally low in VE (NRC, 2001). The best understanding of the role of VE on mastitis and milk production is that it acts as a lipid soluble cellular antioxidant, free radical scavenger and protects against lipid peroxidation.

The beneficial effect of supplementation of VE and BC on milk production has been documented by Chawla and Kaur (2004). Cows were supplemented with 1000 IU α-tocopheryl acetate and 1000 IU α-tocopheryl acetate + 300 mg BC from 30 days prepartum to 2 weeks post-partum, which resulted in increased milk production of cows supplemented VE (14.1 vs. 11 kg/day, $P < 0.01$) and VE + BC (14.6 vs. 11 kg/day, $P < 0.01$). The reason was fewer udder infections during the period in supple-mented cows.

However, in a recent study by Brozos et al. (2009), daily administration of a blend containing 60 g ammonium chloride, 1000 IU VE and 0.05 ppm Se throughout the dry period seemed to be safe, but without any effect on milk yield at 30 and 60 days postpartum. In addition, cows were given intramuscular injections of 2100 mg of VE (and 7 g of sodium selenite) 2 weeks before calving and on the day of calving, but there was no effect on milk yield (Bourne et al., 2008).

Questions still remain on the benefit, optimum dose, route and timing of VE administration in lactational dairy cows. Based on these and numerous other studies, NRC (2001), recommended the VE requirement for milking cows to be 15 to 20 IU/kg dry matter (DM).

SELENIUM

Se is recognized as an essential trace element for do-mestic animals, and it functions in the antioxidant system as an essential component of the glutathione peroxidase, which is responsible for the reduction of H_2O_2 and free O_2 to H_2O (NRC, 2001). It also plays a vital role in protecting both the intra- and extra-cellular lipid membranes against oxidative damage. The majority of Se in body tissues and fluids is present as either selenocysteine, which functions as an active center for selenoproteins, or seleno-methionine, which is incorporated into general proteins and acts as a biological pool for Se (Juniper et al., 2006).

Moeini et al. (2009) reported that daily milk production of heifers at 8 weeks lactation was significantly increased (26.1 vs. 29.4 L/day, $P < 0.05$) and milk SCC decreased (193,000/mL vs. 179,000/mL, $P < 0.05$) by 20mg Se and 2000 IU D, L-α-tocopheryl acetate supplemented at 4 and 2 weeks before expected calving. Wang et al. (2009) evaluated the effects of selenium-yeast supplementation on lactation performance in dairy cows. Treatments were: control, LSY, MSY and HSY with 0, 150, 300 and 450 mg selenium yeast per kg of diet dry matter, respectively. Experimental periods were 45 days with 30 days of adaptation and 15 days of sampling. The results indicate that supplementation of diet with selenium-yeast im-proved the milk yields. Milk yields were higher ($P \leq 0.05$) for LSY and MSY than for HSY and the control but proportions and yields of milk fat, protein and lactose were not affected by selenium-yeast supplementation ($P > 0.05$). The optimum selenium-yeast dose was about 300 mg per kg diet dry matter.

However, Juniper et al. (2006) found no significant effects for different levels of selenized yeast and sodium selenite on milk yield, milk composition (fat, protein, lactose, urea nitrogen and SCC), and yield of milk consti-tuents. Results of selenized yeast on milk yields and milk components are inconclusive. It could be due to differences in the composition of the diet and/or the dose of selenized yeast and lactation period of dairy cows.

The differences presented earlier were due to the Se levels of blood before the experiment and the form, opti-mum dose, route and timing of administration of Se in lactational dairy cows. NRC (2001) recommended that the level of Se in dairy diets is 0.3 mg/kg DM and should be closely monitored to ensure that over supplementation does not occur.

ZINC

Zn is an essential trace mineral which is found to be an integral component of over 300 enzymes in metabolism, and NRC (2001) recommended the level of Zn supple-mentation for lactating dairy cows to be 40 to 60 mg/kg DM. Kellogg et al. (2004) indicated that Zn methionine increased lactation performance (produced more ($P < 0.01$) milk, energy-corrected milk and fat-corrected milk) and improved udder health (as a 33.3% reduction in SCC), but milk composition did not change ($P > 0.15$). Popovic (2004) evaluated replacing 33% of the supplemental inorganic Zn sulphate with organic Zn for 45 days pre-calving until 100 days post-calving. Cows that received the organic Zn had significantly ($P < 0.05$) lower SCC by day 10 of lactation (158,840/mL vs. 193,530/mL) and at the end of the trial (62,670/mL vs. 116,440/mL), the average milk yield was numerically greater (27.75 kg/day vs. 26.22 kg/day). In addition, Kinal et al. (2005) reported that replacing 30% of the inorganic Cu, Zn and manganese (Mn) for 6 weeks pre-calving until 305 days of lactation in dairy cows resulted in a 6.5% increase in milk yield (22.35 vs. 21.20 kg/day, $P < 0.05$) and a 34% reduction in SCC (270,00/mL vs. 409,000/mL, $P < 0.01$).

In a study by Griffiths et al. (2007), supplementing cows with CTM (providing daily 360 mg Zn, 200 mg Mn, 125 mg Cu as amino acid complexes and 12 mg cobalt (Co) from Co glucoheptonate) resulted in ($P \leq 0.05$) a 6.3% increase in milk production, 5.6% increase in milk energy, 6.4% improvement in fat yield, 6.5% improvement in crude protein yield, 5.8% improvement in production of milk solids, and a trend for a reduction in mastitis cases ($P \leq 0.10$). Milk composition was not affected by treat-ment, although fat, crude protein and the solids content of milk produced by CTM supplemented cows were numerically ($P \geq 0.10$) higher than that produced by the control cows. Cope et al. (2009) evaluated the effects of the level and form of dietary Zn on milk performance, and found that cows supplemented with organically chelated Zn at the recommended level had a higher milk yield (37.6 kg/day) than those fed inorganic Zn at the recommended level (35.2 kg/day), or organically chelated Zn at low level (35.2 kg/day), but there was no difference from those fed inorganic Zn at the low level (36.0 kg/day). Milk composition was unaffected by dietary treatment. Animals that received the low level of Zn had higher SCC.

Nocek et al. (2006) reported that first lactation cows had no differences in SCC when fed Zn, Mn, Cu and Co in complex or inorganic form at 75 or 100% of NRC above the basal diets, but a small significant milk production response was noted between the organic and the inorganic minerals, even when the inorganic minerals were fed at 75% of NRC. However, Uchida et al. (2001) reported that feeding a combination of Zn amino acid (AA), Mn AA and Cu AA complexes, and Co glucoheptonate to early lactation Holstein cows had no effect on milk production, milk fat and protein content, and linear SCC.

COPPER

Cu is a component of ceruloplasmin, which facilitates iron absorption and transport. In addition, Cu is considered as an important part of superoxide dismutase, an enzyme that protects cells from the toxic effects of oxygen metabolites produced during phagocytosis. Therefore, lactating cows were recommended for Cu supplementation at 11 mg/kg DM (NRC, 2001). Copper deficiency in cattle is generally due to the presence of dietary antagonists, such as sulfur, molybdenum and iron that reduce Cu bioavailability (Spears, 2003). Dietary requirements for Cu are greatly increased by high concentrations of molybdenum and sulfur.

Scaletti et al. (2003) evaluated the effect of dietary Cu on the responses of heifers to an intramammary *Escherichia coli* challenge at 34 days of lactation. Primigravid Holstein heifers were supplemented with Cu sulfate (20 ppm) beginning from 60 days prepartum through 42 days of lactation. The results suggested that Cu supplementation reduced the clinical response; a reduction in bacterial and SCC lowered the clinical mammary scores and lowered the peak rectal temperatures during experimental *E. coli* mastitis, but the duration was unchanged. In a study designed to evaluate the effects of dietary organic sources of Zn, Cu and Se for dairy cows on SCC and the occurrence of subclinical mastitis, it was found that the number of new and total cases of subclinical mastitis was lower for the group of cows fed with organic sources of Zn, Cu and Se when compared with animals that received inorganic sources. Average SCC during the first 80 days of lactation tended to be lower for the group fed with organic Zn, Cu and Se (Cortinhas et al., 2010).

Assuming normal bioavailability and typical ingredients, an average lactating Holstein cow producing 100 pounds (1 pound = 0.4536 kg) of milk needs to consume about 300 mg Cu/day. Excessive intake of Cu can be toxic (only four to five times more than the requirement) for animals, and Cu supplementation should be avoided unless feed analysis data is indicated.

CONCLUSION

In this review, recent researches on vitamins and trace-element supplements for improving the milk performance of dairy cows was considered. Some vitamins and trace-minerals are clearly documented with their influence, while the impacts of supplementation of some micronutrients on milk performance are less clear. Continued research using field data and controlled studies are needed to further define the role of nutrition on the milk performance of dairy cows.

Before deciding to supplement dairy cow rations with the levels of vitamins and trace-minerals indicated earlier, dairy farmers should have their animal feeds tested and their rations evaluated by a competent dairy cow nutriationist and a trustworthy laboratory to be sure of the level of supplementation that may be warranted. While inadequate intake and absorption of certain nutrients may result in a weakened immune system and perhaps more mastitis and less milk production during the lactation period, unjustified supplementation can be expensive and lead to other animal health problems.

ACKNOWLEDGMENTS

This study was jointly supported by the National Natural Science Foundation of China (No. 30960294), Guangxi Department of Science and Technology (No. 10100014) and Postgraduate Innovation Projects of Guangxi (2009105930905D003). The authors would like to thank Dr. Alan Sparkes of Nipissing University for revising the English manuscript.

REFERENCES

Aréchiga CF, Staples CR, McDowell LR, Hansen PJ (1998). Effects of timed insemination and supplemental β-carotene on reproduction and milk yield of dairy cows under heat stress. J. Dairy Sci. 81(2): 390-402.

Bourne N, Wathes DC, Lawrence KE, McGowan M, Laven RA (2008). The effect of parenteral supplementation of vitamin E with selenium on the health and productivity of dairy cattle in the UK. Vet. J. 177(3): 381-387.

Brozos CN, Kiossis E, Georgiadis MP, Piperelis S, Boscos C (2009). The effect of chloride ammonium, vitamin E and Se supplementation throughout the dry period on the prevention of retained fetal membranes, reproductive performance and milk yield of dairy cows. Livest. Sci. 124: 210-215.

Chawla R, Kaur H (2004). Plasma antioxidant vitamin status of periparturient cows supplemented with α-tocopherol and β-carotene. Anim. Feed Sci. Tech. 114: 279-285.

Cope CM, Mackenzie AM, Wilde D, Sinclair LA (2009). Effects of level and form of dietary zinc on dairy cow performance and health. J. Dairy Sci. 92(5): 2128-2135.

Cortinhas CS, Botaro BG, Sucupira MCA, Renno FP, Santos MV (2010). Antioxidant enzymes and somatic cell count in dairy cows fed with organic source of zinc, copper and selenium. Livest. Sci. 127(1): 84-87.

Girard CL, Matte JJ (2005). Effects of intramuscular injections of vitamin B12 on lactation performance of dairy cows fed dietary supplements of folic acid and rumen-protected methionine. J. Dairy Sci. 88(2): 671-676.

Graulet B, Matte JJ, Desrochers A, Doepel L, Palin M-F, Girard CL (2007). Effects of dietary supplements of folic acid and vitamin B12 on metabolism of dairy cows in early lactation. J. Dairy Sci. 90(7): 3442-3455.

Griffiths LM, Loeffler SH, Socha MT, Tomlinson DJ, Johnson AB (2007). Effects of supplementing complexed zinc, manganese, copper and cobalt on lactation and reproductive performance of intensively grazed lactating dairy cattle on the South Island of New Zealand. Anim. Feed Sci. Tech. 137: 69-83.

Heinrichs AJ, Costello SS, Jones CM (2009). Control of heifer mastitis by nutrition. Vet. Microbiol. 134: 172-176.

Herdt TH, Stowe HD (1991). Fat-soluble vitamin nutrition for dairy cattle. Vet. Clin. N. Am-Food A. 7(2): 391-415.

Jukola E, Hakkarainen J, Saloniemi H, Sani S (1996). Blood selenium, Vitamin E, Vitamin A, and β-carotene concentrations and udder health, fertility treatments, and fertility. J. Dairy Sci. 79(5): 838-845.

Juniper DT, Phipps RH, Jones AK, Bertin G (2006). Selenium supplementation of lactating dairy cows: Effect on selenium concentration in blood, milk, urine, and feces. J. Dairy Sci. 89(9): 3544-3551.

Kellogg DW, Tomlinson DJ, Socha MT, Johnson AB (2004). Review: Effects of zinc methionine complex on milk production and somatic cell count of dairy cattle: twelve-trial summary. Proc. Anim. Sci. 20(4): 295-301.

Kinal S, Korniewicz A, Jamroz D, Zieminski R, Slupczynska M (2005). Dietary effects of zinc, copper and manganese chelates and sulphates on dairy cows. J. Food Agric. Environ. 3(1): 168-172.

Majee DN, Schwab EC, Bertics SJ, Seymour WM, Shaver RD (2003). Lactation performance by dairy cows fed supplemental biotin and a B-Vitamin blend. J. Dairy Sci. 86(6): 2106-2112.

Moeini MM, Karami H, Mikaeili E (2009). Effect of selenium and vitamin E supplementation during the late pregnancy on reproductive indices and milk production in heifers. Anim. Reprod. Sci. 114: 109-114.

Nocek JE, Socha MT, Tomlinson DJ (2006). The effect of trace mineral fortification level and source on performance of dairy cattle. J. Dairy Sci. 89(7): 2679-2693.

NRC-National Research Council (2001). Nutrient requirements of dairy cattle, seventh revised ed. National Academy Press, Washington, DC, USA.

Popovic Z (2004). Performance and udder health status of dairy cows influenced by organically bound zinc and chromium. Ph.D. Thesis, University of Belgrade, Belgrade.

Puvogel G, Baumrucker CR, Sauerwein H, Rühl R, Ontsouka E, Hammon HM, Blum JW (2005). Effects of an enhanced vitamin A intake during the dry period on retinoids, lactoferrin, IGF system, mammary gland epithelial cell apoptosis, and subsequent lactation in dairy cows. J. Dairy Sci. 88(5): 1785-1800.

Rosendo O, Staples CR, McDowell LR, McMahon R, Badinga L, Martin FG, Shearer JF, Seymour WM, Wilkinson NS (2004). Effects of biotin supplementation on peripartum performance and metabolites of Holstein cows. J. Dairy Sci. 87(8): 2535-2545.

Sacadura FC, Robinson PH, Evans E, Lordelo M (2008). Effects of a ruminally protected B-vitamin supplement on milk yield and composition of lactating dairy cows. Anim. Feed Sci. Tech. 144: 111-124.

Scaletti RW, Trammell DS, Smith BA, Harmon RJ (2003). Role of dietary copper in enhancing resistance to *Escherichia coli* mastitis. J. Dairy Sci. 86(4): 1240-1249.

Shaver RD, Bal MA (2000). Effect of dietary thiamin supplementation on milk production by dairy cows. J. Dairy Sci. 83(10): 2335-2340.

Sordillo LM, Shafer-Weaver K, DeRosa D (1997). Immunobiology of the mammary gland. J. Dairy Sci. 80(8): 1851-1865.

Spears JW (2000). Micronutrients and immune function in cattle. Proc. Nutr. Soc. 59(4): 587-594.

Spears JW (2003). Trace mineral bioavailability in ruminants. J. Nutr.133: 1506S-1509S.

Spears JW, Weiss WP (2008). Role of antioxidants and trace elements in health and immunity of transition dairy cows. Vet. J. 176(1): 70-76.

Uchida K, Mandebvu P, Ballard CS, Sniffen CJ, Carter MP (2001). Effect of feeding a combination of zinc, manganese and copper amino acid complexes, and cobalt glucoheptonate on performance of early lactation high producing dairy cows. Anim. Feed Sci. Tech. 93: 193-203.

Wang C, Liu Q, Yang WZ, Dong Q, Yang XM, He DC, Zhang P, Dong KH, Huang YX (2009). Effects of selenium yeast on rumen fermentation, lactation performance and feed digestibilities in lactating dairy cows. Livest. Sci. 126: 239-244.

Weiss WP, Spears JW (2006). Vitamin and trace mineral effects on immune function of ruminants. In: Sejrsen K, Hvelplund T, Nielsen MO (Eds.). Ruminant Physiology. Wageningen Academic Publishers, Utrecht, The Netherlands, pp. 473-496.